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STEAM-TURBINE, GAS-TURBINE, AND COMBINED-CYCLE PLANTS AND THEIR AUXILIARY EQUIPMENT

Experience Gained with Development of Steam Turbine Projects with the Use of Standardized Modules

A. E. Valamin[a], A. Yu. Kultyshev[a, b], Yu. A. Sakhnin[a], and M. Yu. Stepanov[a]

[a] *Ural Turbine Works, ul. Frontovykh Brigad 18, Yekaterinburg, 620017 Russia*
[b] *Ural Federal University, ul. Mira 19, Yekaterinburg, 620002 Russia*
e-mail: skbt@utz.ru

Abstract—The possibilities of decreasing the amount of work required for preparing manufacture of the equipment of gas-turbine, boiler, and steam-turbine units in the design and technological respects through the use of standardized components are pointed out. In parallel with this, a fewer number of design and technological errors is achieved, due to which better quality of the products is obtained. The need to develop a series of standard equipment sizes used in the composition of a combined-cycle power plant is considered. Examples of designing a steam turbine using well-elaborated and proven components together with new ones required according to the turbine operating conditions are given.

Keywords: modular design, design preparation of manufacture, technological preparation of manufacture, standardization, series of standard sizes

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Achieving better quality and higher technical–economic indicators of the manufactured equipment with concurrently reducing the costs and time of its manufacture in order to enter the market with the highest competitive advantages as compared with other producers around the world is a challenging task faced by producers of power equipment.

One of efficient methods for reducing the costs and concurrently achieving a shorter time required to develop and manufacture new types of steam turbines consists in standardization of designs, which allows the following positive results to be obtained:

(i) to reduce the amount of work required for preparing the production in the design and technological respects;

(ii) to reduce the standard list of produced parts and assemblies, as well as the amount of the required accessories and tackles; and

(iii) to reduce the list of own-produced and purchased tools.

Standardization allows better quality of the manufactured products to be achieved owing to the following:

(i) The assemblies being designed can be elaborated to a deeper extent.

(ii) Serial technological operations are elaborated within a shorter period of time.

(iii) Standard technological manufacturing and assembling processes with the possibility of their further automation are used.

(iv) A fewer number of operations for readjusting the process equipment is required.

(v) Methods and procedures for technically checking the purchased billets and manufactured components are developed and perfected.

All the above-mentioned features make it possible to achieve high quality of production specimens and high technical–economic indicators with concurrently reducing the specific expenditure of materials by using improved parts and assemblies, final choice of the optimal type of billets and decrease of nesting coefficients. In addition, which is of no small importance, the manufacturer becomes able to develop within quite a short period of time a considerable amount of equipment types needed in the market.

In our previous publication [1], we already pointed out that for implementing the investment program for developing the Russia's power industry, the Ministry of the Russian Federation for Industry and Power should work out and approve a series of standard sizes of "gas-turbine unit (GTU)–heat-recovery boiler (HRB)–steam turbine unit (STU)" modules for constructing combined-cycle power plants (CCPs). Not only will it make possible to carry out work on agreeing and constructing power stations within a shorter period of time, but it will also help to reduce the equipment procurement costs, and open the possibility for the producers to reduce the cost of equipment manufacture and to more firmly compete with foreign suppliers by producing modern equipment for power industry applications.

A limited series of standard sizes of sets for HRB–STU modules used in Russia for each GTU has not been defined as yet, and power companies, general contractors, and design and research institutes develop

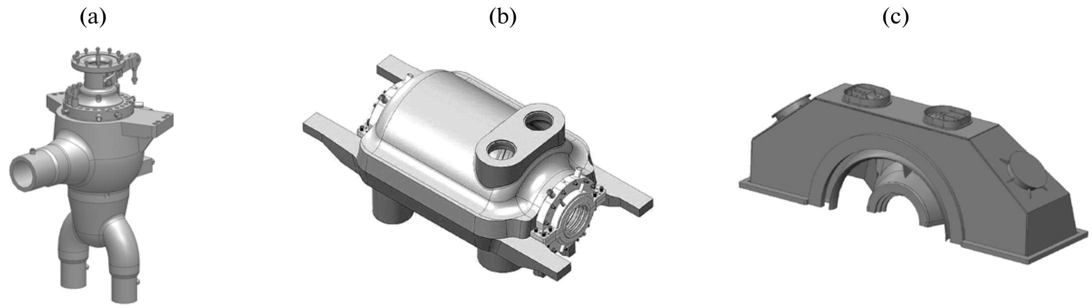

Fig. 1. Examples of elements in the “library” of universal modules. (a) Stop-and-control valve, (b) high-pressure cylinder outer casing, and (c) upper half of the low-pressure cylinder exhaust part.

new HRB and STU projects with absolutely different compositions of equipment and with different process circuits and parameters, which are often far from being the optimal ones. Manufacturers develop and produce new equipment for almost each order that must comply with the contractual requirements and conditions. In so doing, the manufacturers have to spend great material resources and manpower for preparing the production facilities in the design and technological respects and for launching the production of new equipment. Not only is this situation far from being an engine of progress, but it even becomes a hindrance, because sufficient money cannot be earmarked for research and experimental development works.

In view of what was said above, the problem of using standardized components within an equipment set is becoming increasingly more important, and this is why UTZ specialists use modular designs on an increasingly larger scale in developing steam turbines. In so doing, components and modules (large assembly units) are designed that take into account not only the specific features of a particular project, but also the possible prospect of using them for standardization in

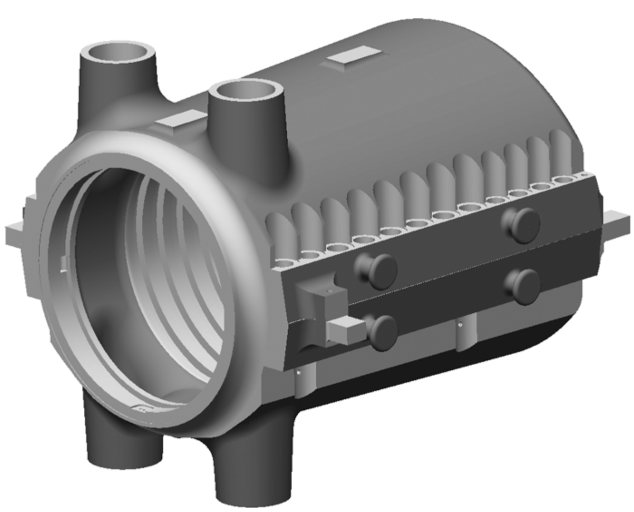

Fig. 2. General view of the turbine cylinder inner casing.

the next project for a certain range of characteristics and parameters. For example, a large structural element can be “artificially” subdivided into two or three ones, which will comply with the requirements of structural independence and standard sizes. This will make it possible to standardize some components and replace other ones, i.e., to use the principle of the LEGO toy construction set.

The systems approach to modular designing consists in the following. Those who design components for a new turbine must consider the possibility of using these components in the future in other turbines of close standard sizes. The following conditions should be fulfilled for implementing this principle:

(i) Components are subdivided into a larger number of subcomponents (modules) than it is required in the project for creating elements prospective for use, despite the fact that some more effort is required for accomplishing the development.

(ii) Universal means for interconnecting the modules are elaborated.

(iii) The possibility to operate in certain ranges of steam pressures and temperatures is calculated and laid down in the design of modules without a significant increase of metal intensity.

(iv) The designs are perfected for production friendliness.

(v) Efforts are taken to do away with designing unique dedicated assemblies and parts, which will make it possible to form and increase the scope of a modular series, i.e., the “library” of universal modules (Fig. 1).

Thus, having developed five projects of steam turbines for different steam parameters for CCPs with capacities ranging from 30 to 200 MW, it is possible to fill the series of standard sizes with the required number of turbine design versions by composing them from standardized modules for particular parameters. For example, the cast cylinder casing made of Grade 15Kh1M1FL steel that was developed for T-63/76-8.8 [2] and KT-63-7.7 single-cylinder two-casing turbines used as part of the PGU-230 combined-cycle power plant has been used in the T-40/50-8.8 turbine [3] for operation as part of the PGU-115 combined-cycle plant (Fig. 2). With this

solution, it becomes possible to standardize the assembly for supplying high-pressure steam to the turbine steam admission chamber formed by the casing inner surface and the outer surface of the intermediate seal holder and the principle of resting on the cylinder outer shell by means of four support legs, two of which (the transverse ones) are arranged along the cylinder steam admission axis, and the two other ones are arranged in parallel to the longitudinal axis, and a number of other items.

With the height of turbine last-stage rotor blades equal to 550 mm, the same type of cylinder exhaust hoods can be used, which also makes it possible to partially standardize the couplings with other equipment parts. One of such modules, namely, the lower half of the cylinder exhaust hood used in T-40/50/8.8 and Tp-35/40-8.8 turbines [4] for CCPs and in T-50/60-8.8 and K-63-8.8 turbines [5] for a steam power unit, is shown in Fig. 3.

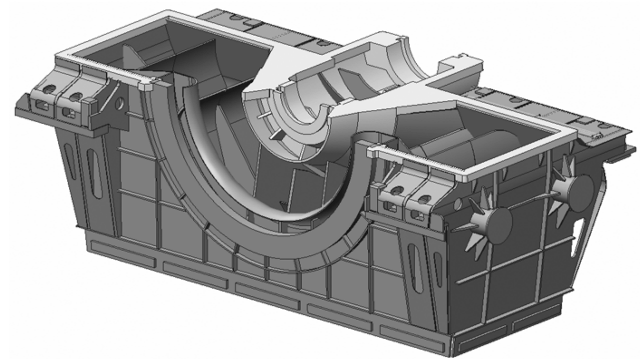

Fig. 3. General view of the turbine cylinder exhaust hood lower part.

Some other turbine components can also be standardized, opening the possibility to use solutions well proven during operation and to earmark money for improving them. Figure 4 shows the longitudinal section of the T-40/50-8.8 turbine, which has been designed with the use of existing and new solutions [6]. Some of the above-described modules are indicated in Fig. 4.

Design and technological preparation of the project using a modern CAD/PDM/PLM/CAM tool taken in combination with the modular design principle open the possibility to efficiently use the establishing of associative links between the design and technological models. The only thing that has to be done in this respect is to construct a unified information field (environment) for design and technological tasks [7]. Information required for technological designing, which is available in the design part of the system integrated into the technological part, is transmitted to the technological part, and the information on the designed tackles, billets, operation sketches, and numerical program control (NPC), which is stored in the technological part, is transmitted to the design part of the system.

Engineers who develop steam turbine and turbine equipment components face the need to solve various design and technological problems, such as the following ones:

—constructing the technological process structure;

—designing the billets;

—designing and selecting the means for technological fitting (equipment, accessories, and tools);

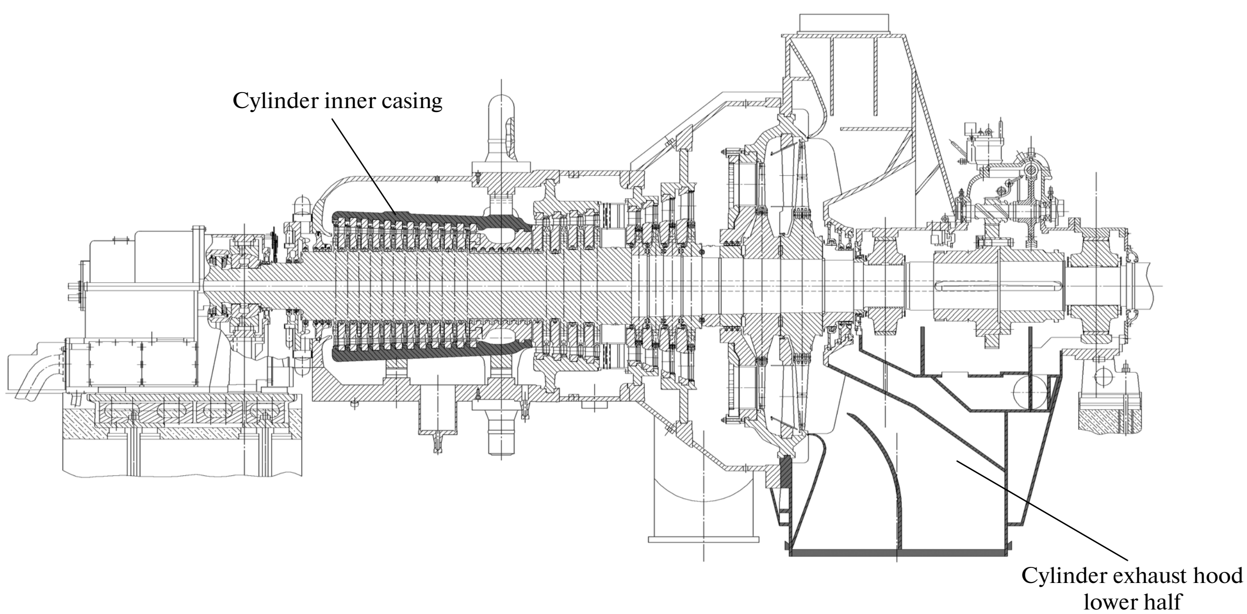

Fig. 4. Longitudinal section of the T-40/50-8.8 turbine.

—assigning the technological operations and transitions;

—determining the processing regimes;

—determining the norms for expenditure of materials and manpower; and

—developing the control programs for NC machines.

In using a modular principle of designing and a unified information field for preparing the production facilities in the design and technological respects, i.e., a unified and interconnected CAD/PDM/PLM/CAM complex, a high degree of design work automation can be achieved. For example, the Creo/Windchill/Creo computer programs are used at the UTZ for this purpose.

If a new version of the 3D model appears in the course of work with an associatively linked technological presentation, the system warns the user about the change, and on receiving the acknowledgment, the system automatically updates the results of technological tasks. With such an arrangement, it is possible not only to accomplish redesigning within a shorter period of time, but also to avoid design and technological errors.

One issue that is of importance in developing a technological process is to ensure that valid production facilities actually used at the enterprise were indicated in the project. The use of the Windchill PLM system at the UTZ opens the possibility to manage the library of physical resources and manpower and to keep it in updated state.

At present, the technological process is developed after completing the structural design. In using a ready design module or a module altered by parameterization, it is possible to complete technological preparation of the production facilities concurrently with completing the design process, which will make it possible to maximally decrease the net cost and to manufacture such equipment within a shorter period of time.

The use of modular designing and ready-made and parameterized standardized modules will open the possibility to launch the production of new equipment specimens with costs, production time, and quality commensurable with those of serially produced articles.

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